

R-F Transmitter Modular Sub-Assemblies

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1. Summary

This report covers the third bi-monthly period of the engineering program. It includes a discussion of the basic module design and development progress, and electro-mechanical design and development progress. In addition a group of illustrations including schematics and photographs are shown exhibiting progress to date.

2. Introduction

During the first two report periods time was devoted entirely to the design and development of cubically shaped modules. After an experimental model system of this type was delivered to the sponsor, he requested that we change our design approach to the development of the "smallest practical size" (with flat sides) modules. This report is the first that presents information concerning this revised packaging scheme. Thus far at least one circuit for each type of basic module required for these transmitting systems has been reported. These were chosen from a group of experimental circuits as the most suitable for the application. Therefore it becomes a matter of eliminating "bugs" and modifying these basic circuits to fit into the various systems. Modulation methods and the tuning indicator are still in the investigation stage to determine the most desirable means of accomplishing these procedures. It is hoped that when the 4th report is submitted a complete 1/2 watt basic module system will have been submitted for acceptance.

3. Basic Module Design and Development

3.1 RF Circuits

3.1.1 Crystal Controlled Oscillator

Minor changes have been made in the rf oscillator that was previously reported. The most significant of these being the redesign of transformer T1 in Figure. 1. This circuit is capable of delivering 25 mw to a 50 ohm load from 3Mc to 7.5 Mc. The waveform is essentially free of distortion. Its efficiency decreases from 35% at the 3 Mc end to 19% at the 7.5 Mc end. A packaged module of this circuit is exhibited to the right of the postage stamp in Figure 11. A completely encased unit with the crystal inserted lies in the upper left corner of Figure 12. This oscillator has been temperature tested from -50°C to $+60^{\circ}\text{C}$. Its power output varies only slightly, and its frequency change can be attributed to the temperature characteristic of the crystal unit. Preliminary keying tests on the oscillator have revealed no serious defects in this method of keying. Application of this technique should result in the elimination of the oscillator radiation problem that was noted in the first experimental model A1 system where the power amplifier was keyed and the oscillator was operating continuously.

An oscillator similar to this one is being designed and developed to deliver approximately 25 mw to a 50 ohm load from 7.5 Mc to 15 Mc.

3.1.2 Untuned Power Amplifier for the 1/2 Watt Systems

Two major changes have been made in the design of the 1/2 watt power amplifier. The first is the replacement of the 5639 tube with a 5902A. The 5902A characteristics are more suitable for Class A1 power amplifier service. Its grid can be driven with a much larger peak to peak voltage; therefore the design of the input circuit becomes less critical, and there is less possibility of grid "over-drive" distortion. The output transformer tuning is eliminated by utilizing a wide band transformer. A low-pass filter is attached to the output to reduce 2nd harmonic distortion. With the oscillator of Figure 1 as a driving source, the rf output into a 50 ohm load is 0.75W at 3Mc and 5Mc, and reaches a maximum of 1.0W at 4Mc. The plate efficiency of this circuit varies from 23 to 30% depending on the operating frequency. The high filament power requirement (2.84W) reduces the overall efficiency to 12.2 to 16.3%. There is little chance of increasing these efficiency figures greatly for this type of design since the limiting factors are high filament power (inherent in beam power pentodes necessary for the circuit), and low plate efficiency (inherent in Class A1 service).

3.1.3 15 to 30 Mc Doubler-Amplifier for the 1/2 Watt Systems

The schematic diagram of a 15 to 30 Mc Doubler-Amplifier is shown in Figure 3. This circuit includes a 15 to 30 Mc frequency-doubler that can be driven by a 7.5 to 15 Mc oscillator similar to the one of Figure 1.

It will produce enough power when C2 is tuned properly to drive the power output stage V2. Stage V2 will deliver more than 0.75W at the output into 50 ohms from 15 to 30 Mc if C5 is tuned properly. T1, T2, and T3 are miniature toroidal transformers. C2 and C5 are specially designed miniature variable teflon capacitors (see Section 4.3). This circuit operates at an overall efficiency of approximately 14%. This poor efficiency can be attributed to the very low doubler efficiency. The basic module package is being constructed.

3.1.4 Power Amplifier for the 5 Watt Systems

Several breadboard circuits have been tried in order to determine the optimum design for the rf power amplifier for the 5 watt systems. The tube used in the first breadboard was the Sylvania experimental ceramic metal tube type SN2146B. Fifteen of these tubes were obtained from Sylvania as G.F.E. This tube is quite similar to a 6 AQ5 electrically, but physically is much smaller and much more rugged. Its construction was described recently in the October, 1957 issue of "Electronics". Circuit design was hampered by the lack of operational data. It was determined that this tube is unsuitable for class "C" rf service. It has excessive control grid to plate capacitance which makes neutralization necessary. It also has a tendency to draw excessive screen current when operated at high peak plate currents. This characteristic is typical for this type of tube. In order to allow increased dissipation rating, and to overcome screen current difficulties the SN2146B was tested in a triode connected circuit.

Although triode operation eliminated some of the problems encountered in pentode operation, to obtain sufficient power output a greatly increased grid drive was necessary.

As an alternate approach a 12AU7 with two halves tied in parallel was used in a breadboard circuit. This circuit was placed in a modular package 2-1/4" x 1-3/4" x 1-1/4". This unit verified that crowding components inside a metal enclosure does not drastically affect circuit performance if toroidal tank coils are utilized.

Although the SN2146B breadboards and the 12AU7 unit would deliver 5 watts or more at the antenna terminals of the antenna coupler, they required precise adjustment with the tubes operating at their maximum ratings. To provide 5 watts with less critical adjustment and more conservative operation two SN2146B's connected in parallel resulted in the circuit of Figure 4. This circuit has performed satisfactorily from 3 to 6 Mc and at 30 Mc. A modular package of this circuit can be seen on Figure 13.

The two most severe problems to be solved in packaging this circuit in an extremely small case are the design of reliable miniature variable tuning capacitors, and controlling the distribution of heat for reliable operation.

Two additional tubes are to be investigated to complete experimentation with this circuit. The first is the RCA 6417. It is a low cost non-premium transmitter tube in a 2-3/8" T6 1/2 bottle and should result in higher overall operating efficiency. The second is the G. E. 5686.

It is a high-reliability type low cost power amplifier pentode in a 1-15/16" T6 1/2 bottle. The 5686 should result in a much smaller, highly efficient, and more reliable module, but will probably produce less power output than the 6417.

3.2 Modulator Circuits

3.2.1 Microphone Pre-Amplifier

Figure 5 is the schematic diagram of a three (3) stage microphone amplifier with a two (2) stage AGC loop. It is designed around the Bogue 2N160 and the Bogue 2N160A silicon transistors. These transistors were selected primarily for temperature stability and because of their case shape (requiring small mounting area). The 2N160A was selected because of its high (+5V) emitter voltage rating. The "mike" amplifier consists of stages Q1, Q2, and Q3. Q4 is the AGC amplifier, and Q5 is the AGC control circuit. The open loop and closed loop gain curves are shown in Figure 9. These curves were obtained with the amplifier input adjusted to accept the output of the Shure MC-30 microphone cartridge. The 5 M V as distortion level is no problem with this "mike" since it will never produce this much output. The amplifier frequency response curve is essentially flat from 50 cps to 20 kc. With the Mc-30 microphone the overall frequency response limits are approximately 400 to 3500 cps.

The photograph of Figure 14 exhibits this pre-amplifier packaged in a case measuring 7/8" x 1-7/8" x 3-5/8". In front of it is a "mini-mike" manufactured by Shure Bros. and designated as a Mc-30. This microphone

is the smallest that has been found commercially available. It is $1/2'' \times 1/2'' \times 1/4''$. Its frequency response curve of Figure 10 can be compared with the Figure 11 frequency response curve of a much larger "small" mike, the Telex model 100. The Telex dimensions are $1'' \times 1'' \times 3/4''$.

3.2.2 Clipper-Filter

The schematic diagram of the Clipper-Filter circuit is shown in Figure 6. It consists of a twin silicon diode clipper and LC low pass filter network. This circuit is isolated from the pre-amplifier and modulator amplifier by input and output transistor buffer amplifiers. The clipping level is adjusted to 12 db, and the filter rolls off at 6 db/octave starting at 3 Kc. This circuit is in the packaging stage.

3.2.3 1Kc Oscillator

Figure 8 is the schematic of a 1 kc silicon transistor oscillator that is to be used as the side tone oscillator in the A1 systems, and as the modulator tone generator in the A2 systems. It is in the packaging stage.

3.2.4 Power Amplifier for the 1/2 Watt Systems

A 1/2 watt system modulator amplifier as shown in Figure 7 is being breadboard tested. The pre-driver accepts the audio signal from either the master 1 kc oscillator or the microphone amplifier and clipper-filter circuits. The 2N160-A transistor was used in this stage, but an attempt is being made to replace it by a 2N160 transistor. The driver stage is a 2N332 which is the electrical equivalent of the 2N160 transistor, but has a Jetec 30 case.

The power stage consists of two medium power 2N497 transistors

operating class-B push-pull. The 1 watt output is more than enough to plate modulate the 1/2 watt rf power amplifiers 100%.

The use of a class-A single ended transistor stage is under consideration in place of the class-B push-pull stage. This would result in poorer efficiency, but would make the transformer design problems less critical.

4. Electro-Mechanical Design and Development

4.1 Miniature Switch

The switch shown in Figure 17 has been designed to switch inductance and capacitors in the antenna coupler network. It is nearing completion of development. Designed around an epoxy glass etched single pole 12 position switch plate, it measures $3/4" \times 3/4" \times 7/16"$. It has a recessed slotted shaft for screwdriver control.

4.2 Miniature Hand Key

The design of the miniature hand key has been finalized. It is shown in Figure 12 as a component of the 1/2 watt basic module A1 system. In Figure 16 it is mounted on the inside surface of the hinged cover of a 1-1/2" cubical case. Figure 16b shows the cover closed. Figure 16a shows it in an open operating position. A small slide latch is provided to hold the key cover in a closed position. When the latch is opened the key cover is pulled down and locked in the operating position by spring loaded slotted hinges. The locks are released by depressing them with two fingers, and the cover can be pushed back and latched.

This key incorporates all of the features of a standard hand key such as the one on the right of Figure 12. It has been approved and accepted by the sponsor.

4.3 Miniature Variable Capacitor

At an early stage it was realized that a miniature highly reliable and stable wide range tuning capacitor would be a necessary component for

packaging small tunable rf circuits. The only types available commercially with sufficient capacitance range are mica dielectric compression and teflon dielectric rotary. The mica compression types are small enough but are generally considered unreliable because of the fragile nature of the mica dielectric. The teflon rotary types are too large. Therefore the design and development of a variable capacitor suitable for the application was initiated. The first experimental model of a parallel plate variable capacitor with a teflon dielectric is pictured in Figure 18 along with a 1/2 Watt Doubler-Amplifier case showing this types of capacitor mounted internally on the end plate. It is screw driver controlled and requires approximately 2-1/2 turns to cover its range. It has been designed to have a nominal capacitance range of 10 uuf to 250 uuf. An improved version of this component with a .0005 inch teflon dielectric is now under development and should be completed during the next period.

4.4 Dual Control Concentric Shaft Switch

Pictured in Figure 19 is an improved version of the antenna coupler switch that was described in Report No. 1. It is designed around an epoxy glass etched switch plate. The switch plate has two concentrically located single pole multi-position sets of contacts etched with finger tip control surfaces on their protruding ends. This will be changed to screwdriver control on the next and final version. The over all dimensions of the switch will be reduced to 1-5/8" x 1-5/8" x 1-5/8". The low frequency or Band No. 1 antenna coupler network is constructed around the shafts of this switch.

Preliminary measurements have shown that the etched switch contact surfaces will result in a contact resistance of less than .02 ohms.

5. Components and Materials Evaluation

5.1 General

Two problems concerning electronic components arise in micro-miniature design that are practically non-existent in standard size design. These are labelling on the part of the manufacturer, and handling and ease of usage on the part of the user. Labelling becomes more difficult as the size decreases. So does handling and usage. Poor or illegible labelling can result in the selection of incorrect values from a parts bin. Illuminated magnifiers are very helpful in reading numbers, letters, or colors on components and counting turns on small single layer transformers, thereby reducing the possibility of placing incorrect values in assembled packages. If incorrect values are placed in final packages replacement becomes very time consuming and therefore very costly. It also becomes increasingly more difficult to preserve the neatness of an extremely small electronic package because there is little or no room to work with tools once the units are assembled. Components such as resistors, transistors, and tiny transformers demand extremely cautious handling. Solid transistor leads will break off where they enter the transistor housing if they are flexed too often. Tiny transformer leads will pull loose from the transformer body if an excessive pull force is applied to them. The bodies of small 1/4 w and 1/10 w resistors fracture more easily than the conventional 1/2 w types. Ferrite materials are fractured easily by severe mechanical shock. Their electrical characteristics can also be altered by severe thermal and mechanical shock.

Environmental and electrical test limits are adjusted to agree with the conditions under which the components or materials will actually be operating within the contract specifications. This should result in highly reliable and long life "e" equipment.

5.2 Components

5.2.1 Ceramic disc capacitors

For rf by-passing usage the Centralab DDM series of low voltage miniature ceramic capacitors was selected. This series was chosen because of its very small size and reasonable cost. Several "short" failures of the .02 mfd. DDM-203 type while operating well within the manufacturer's specified limits forced us to investigate the reliability of this component. Capacitor resistance measurements at 150v dc were made on a group of ten new capacitors. The resistance of nine of the group varied from 2.4×10^{10} ohms to 9×10^{10} ohms. The tenth appeared to "short" intermittently. The measurements of seven of the capacitors revealed a very unstable resistance. On the basis of the operating failures and test results the DDM-203 is considered an unreliable component and therefore will not be used. The .01 mfd. DDM-103 and the .005 mfd. DDM-502 types have given no trouble in operation thus far.

5.2.2 Silver mica capacitors

Earlier tests revealed an unstable capacity condition in the Micamold miniature silver mica capacitors (see Report No. 2). Since then they have been replaced with a similar type, the El-Menco Dm15.

Sample lots of ten each of the El-Menco capacitors have passed capacitance and Q qualification tests at 30 Mc, and temperature tests from -50°C to $+60^{\circ}\text{C}$ without any failures. The only way in which the Micamold MQ15 proved superior to the El-Menco DM15 was in marking. 19 of 375 DM15's had illegible markings.

5.3 Materials

5.3.1 Ferrites

Two types of ferrite material are being utilized for rf transformer and coil cores. These are the General Ceramics Q-1 and Q-2. The Q-1 material is specified by the manufacturer as a 200 Kc to 30 Mc ferramic, and the Q-2 as a 10 Mc to 100 Mc ferramic. Since the magnetic shock, and exposure to elevated temperatures, samples of transformers and coils utilizing these ferramics as cores will be tested periodically to confirm the manufacturer's claim that they display remarkable magnetic stability.

Three coils of No. 30 Formvar wire wound on Q-1 1/4 inch rod cores, and three coils of No. 30 Formvar wire wound on Q-1 3/4 inch flat strip cores were subjected to shock and temperature tests. The shock test consisted of six impacts of 95 G's 3.5 milliseconds duration; 3 impacts parallel to the coil major axis, and 3 impacts perpendicular to the coil major axis. There were no significant changes detected in the inductance of the coils following the shock. The same coils showed no significant change in inductance as the coil body temperature was increased to $+65^{\circ}\text{C}$. These coils ranged in inductance from 10 micro-henries to 100 micro-henries.

5.3.2 Epoxy resin

The modules will be potted with Houghton Labs. "Hysol" 6020-845 silica filled epoxy resin. This resin was recommended for the application by our Paramus plant components section. It is a room temperature setting resin with very desirable electrical and physical properties. To test this compound's power dissipating characteristics after it hardens several cubical blocks were made with a 20 watt resistor imbedded in each. Various levels of dc power were dissipated in the blocks via the resistors and the surface temperature of the blocks was measured with a thermocouple. Results of the tests are tabulated below.

No.	Block Size	dc Power	Max. Temp.
		watts	°C
1	1-1/2 inch cube	4	44
		6	59
		8	69
		10	80
2	2 inch cube	4	31
		8	46
		12	57
		16	68
3	3 inch cube	10	66
		15	75
		19	80

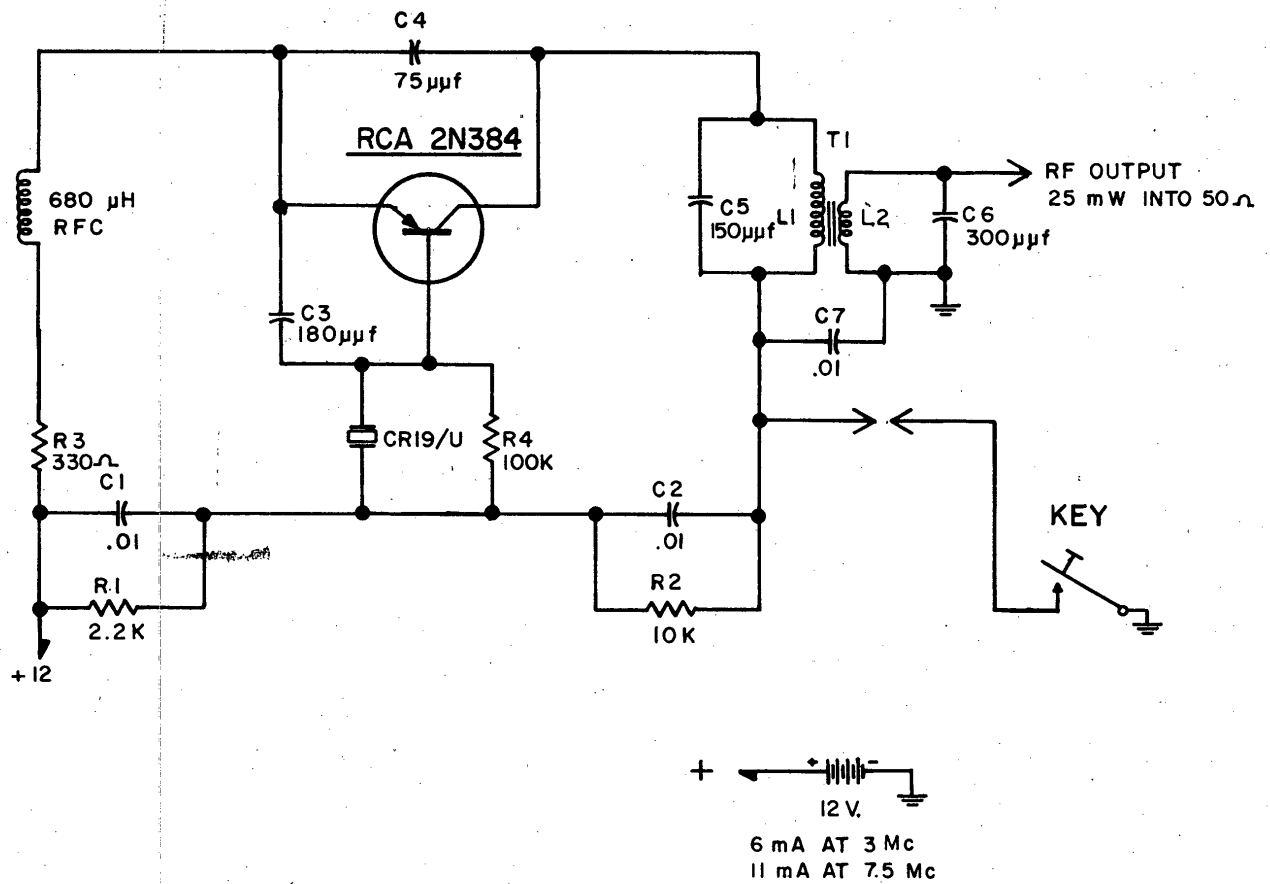


FIGURE I
3-7.5 MC TRANSISTOR R-F OSCILLATOR

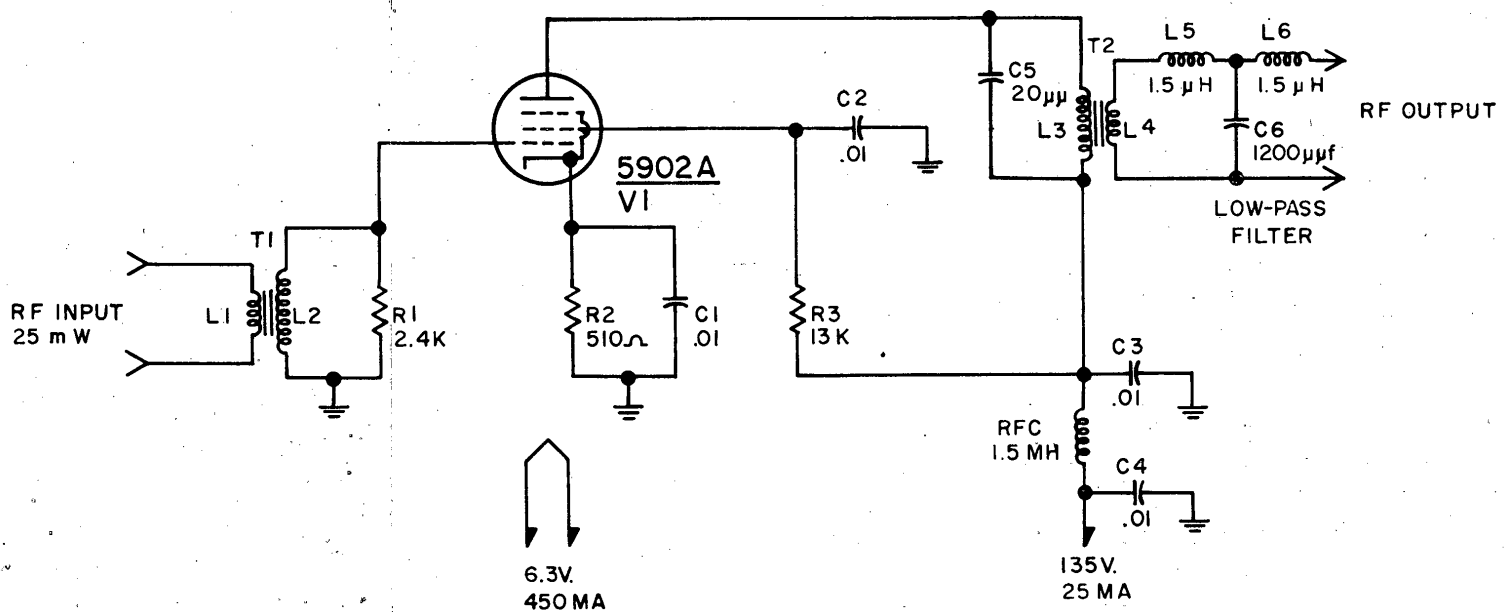


FIGURE 2
 UNTUNED RF AMPLIFIER FOR 1/2 WATT SYSTEM 3-5.4 MC BAND

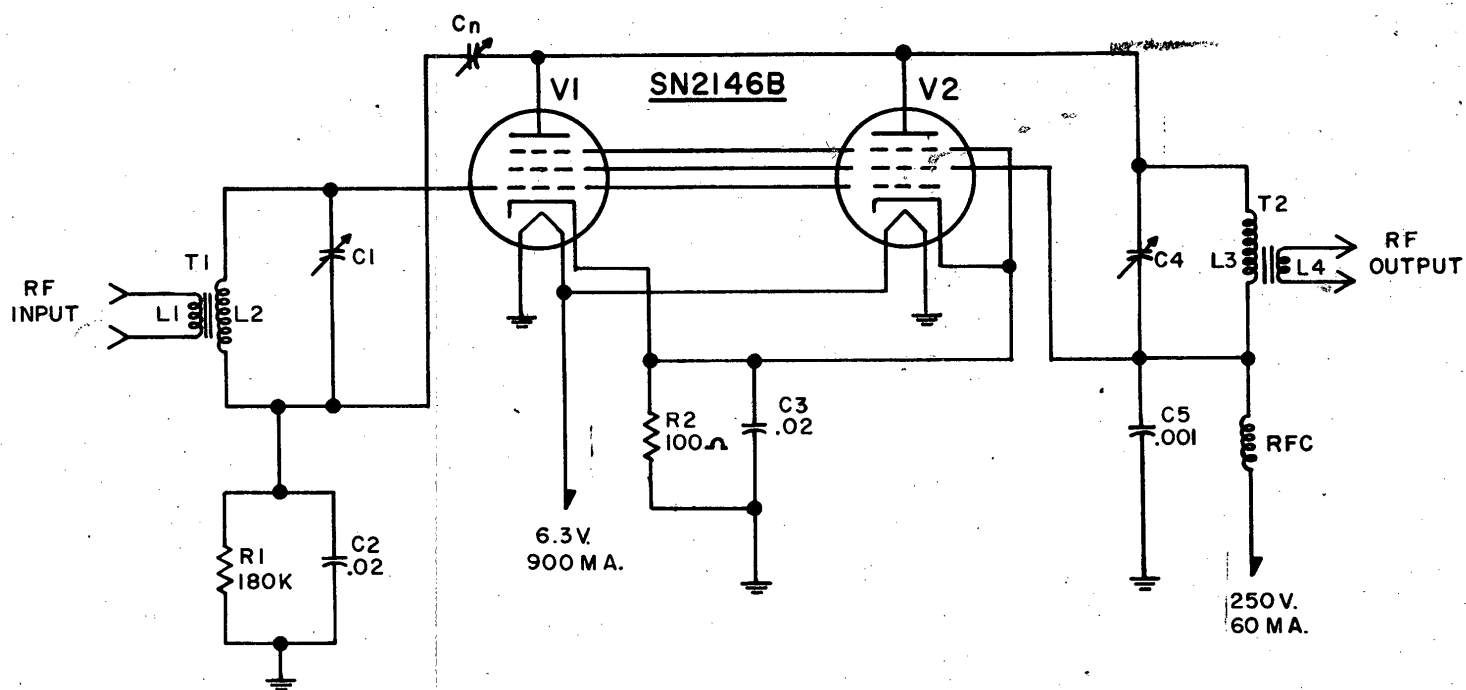


FIGURE 4

RF AMPLIFIER FOR 5 WATT SYSTEM 3-5.4 MC BAND

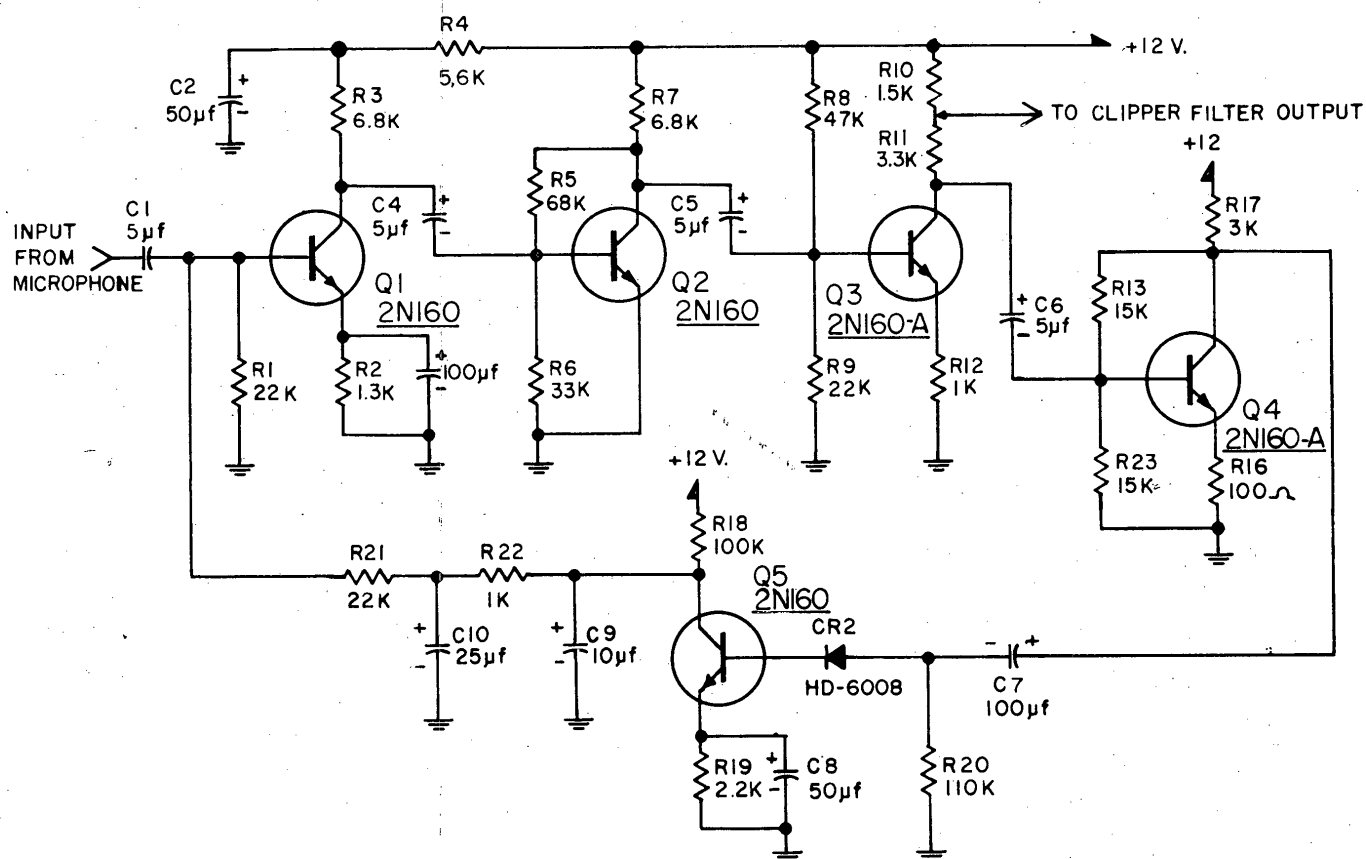


FIGURE 5
MICROPHONE PRE-AMPLIFIER

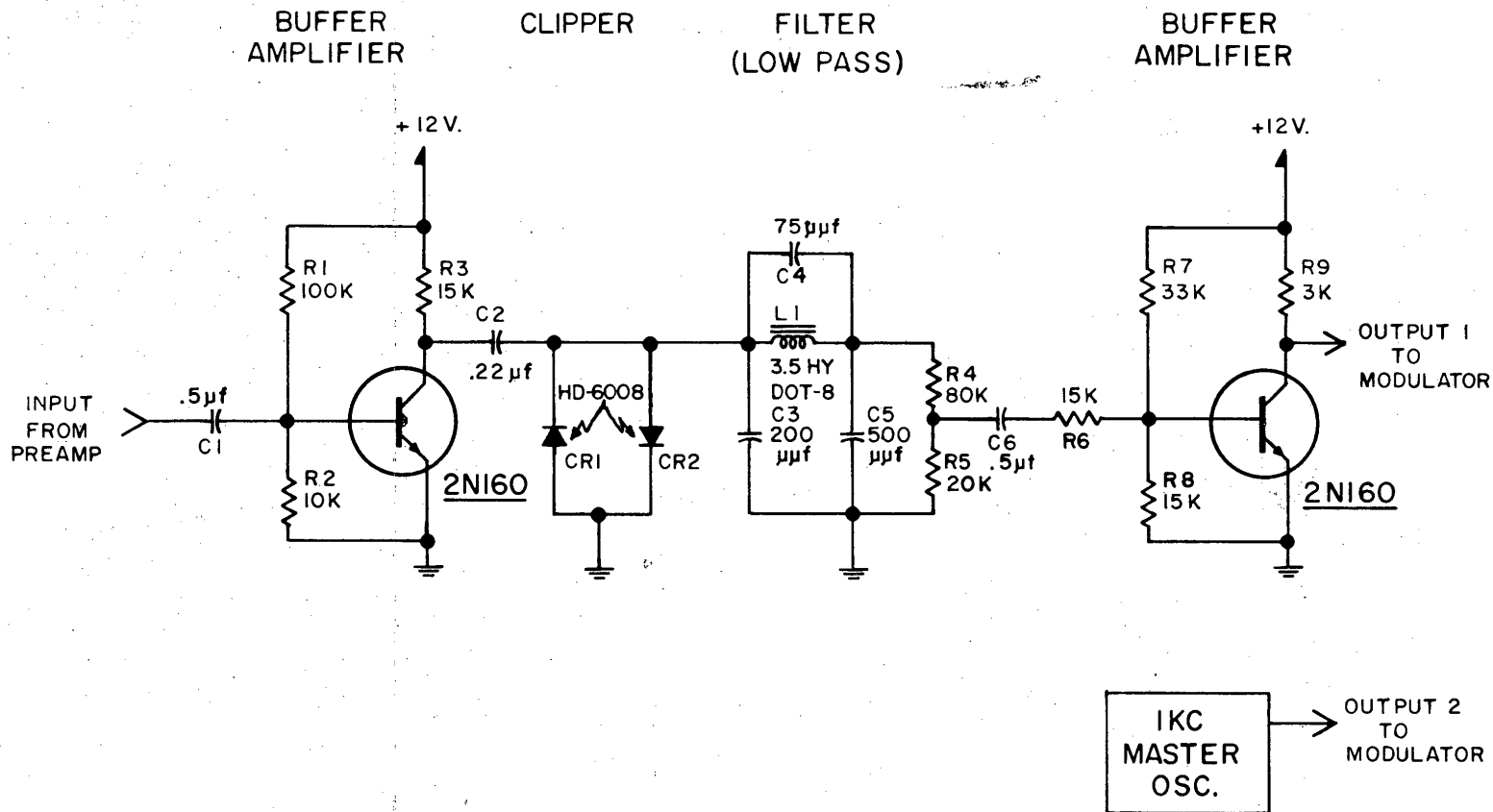


FIGURE 6

CLIPPER - FILTER AND 1KC MASTER OSCILLATOR

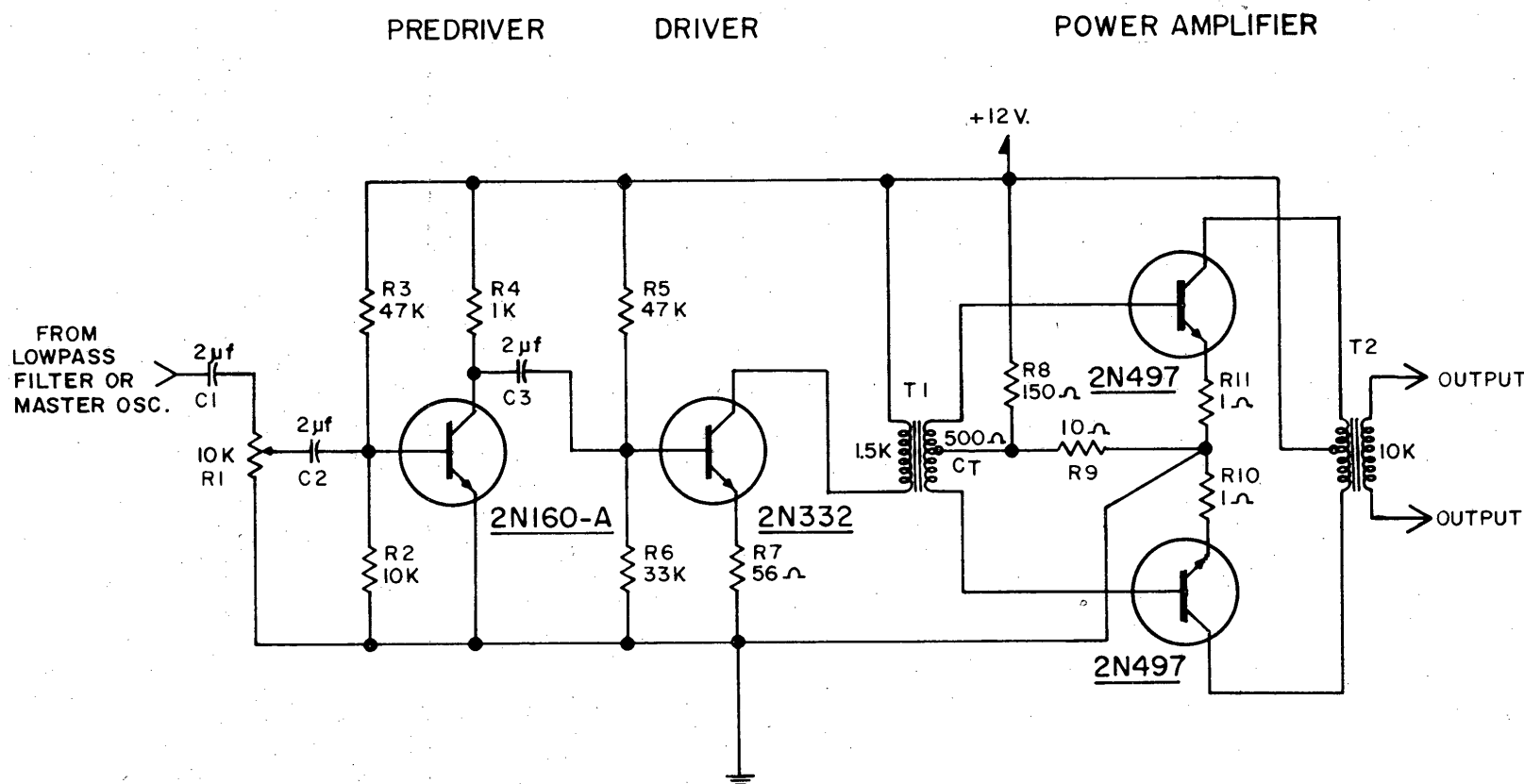


FIGURE 7
1/2 WATT SYSTEM MODULATOR

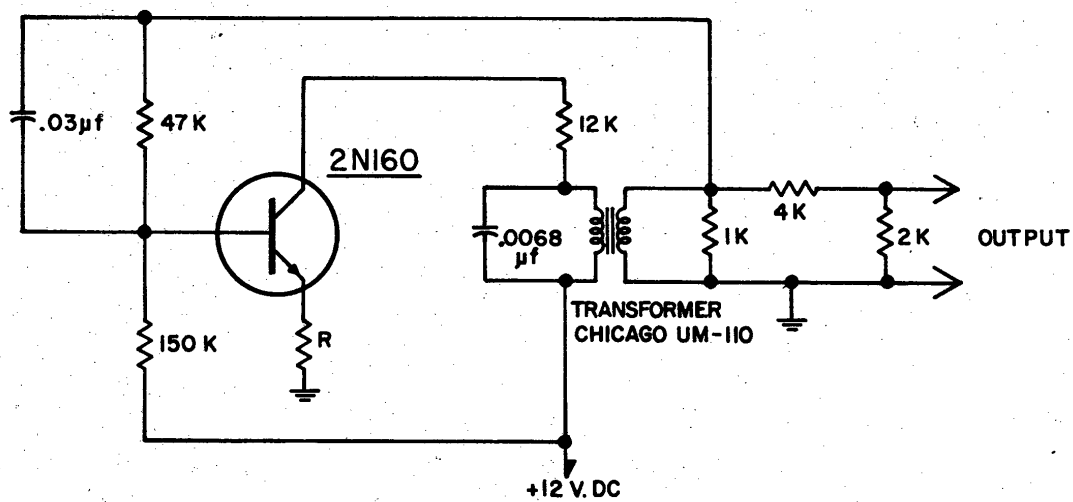


FIGURE 8
1 KC OSCILLATOR

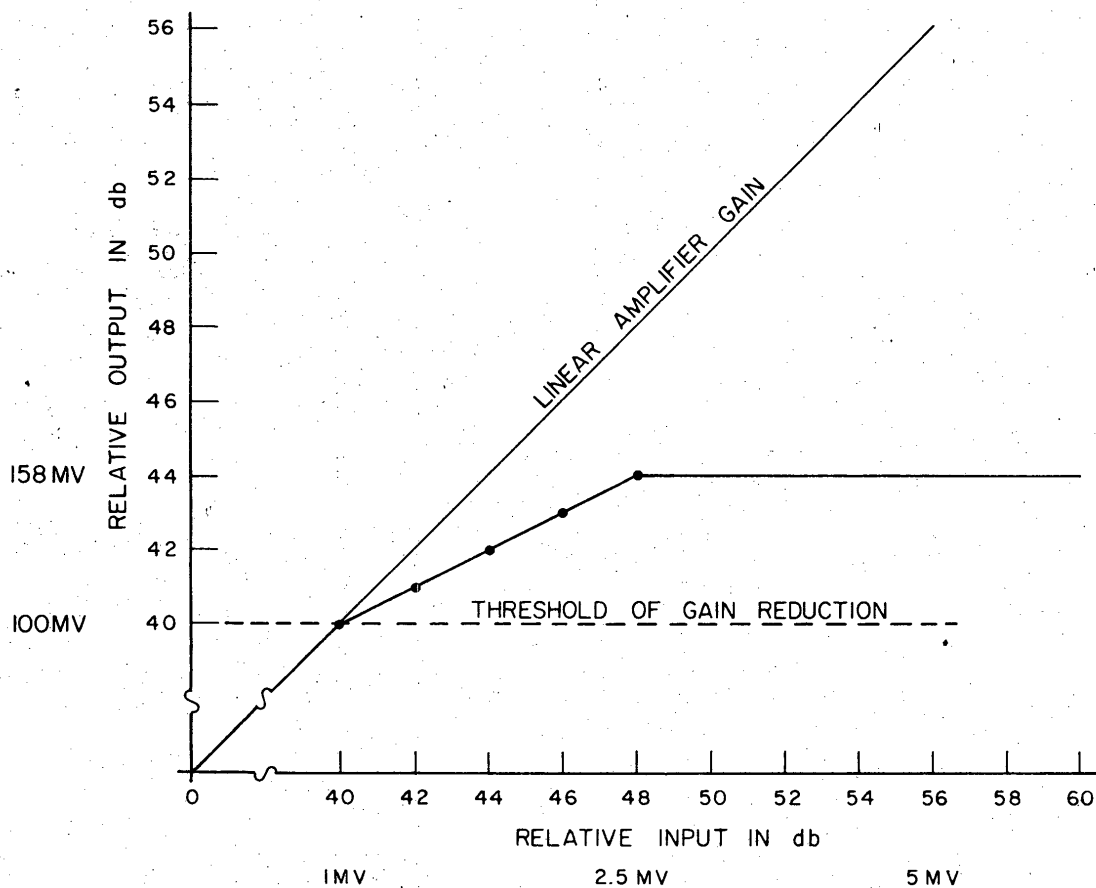
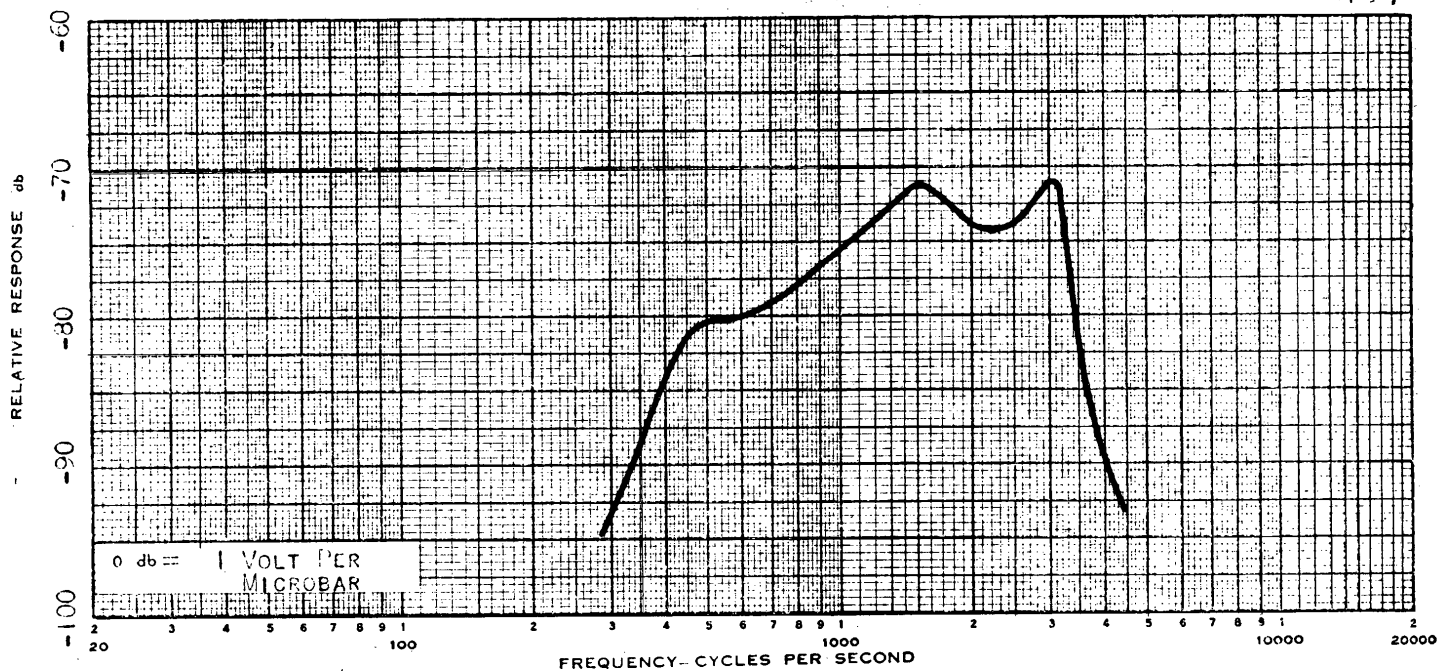


FIGURE 9
PREAMPLIFIER A.G.C. CONTROL

RESPONSE FREQUENCY CHARACTERISTIC

ISSUE NO 2

ISSUE #3



SUBJECT: CONTROLLED MAGNETIC MICROPHONE CARTRIDGE MODEL: NC30 / SERIAL: TYPICAL IMPEDANCE: 1850 OHMS AT 1 KC.
 TEST CONDITIONS: MEASURED IN A FREE FIELD AT A DISTANCE OF 12" FROM SOUND SOURCE. NOMINAL LEVEL PER MICROBAR.

REMARKS: OUTPUT VOLTAGE MEASURED ACROSS 2,000 OHMS.

SHURE BROTHERS
INCORPORATED

Microphones ~ Electronic Components
 222 HARTREY AVE. EVANSTON, ILL., U.S.A.
 PHONE DAVIS 8-9000 CABLE SHUREMICRO

Figure 10

PREPARED BY: SC	DATE: 8/20/57
CHECKED BY: A	DATE:
CHECKED BY: /	DATE:
	DATE: 11/1/57

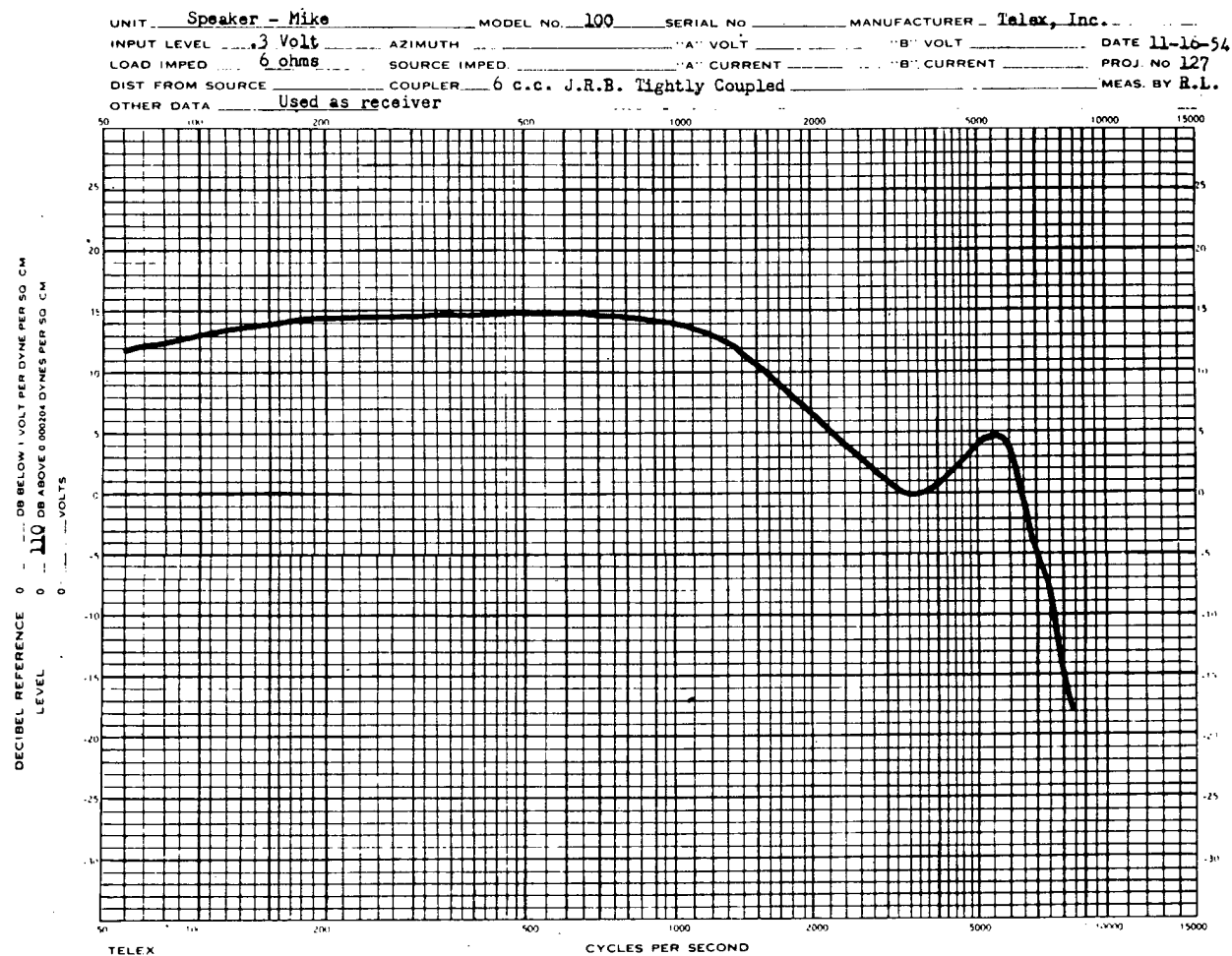
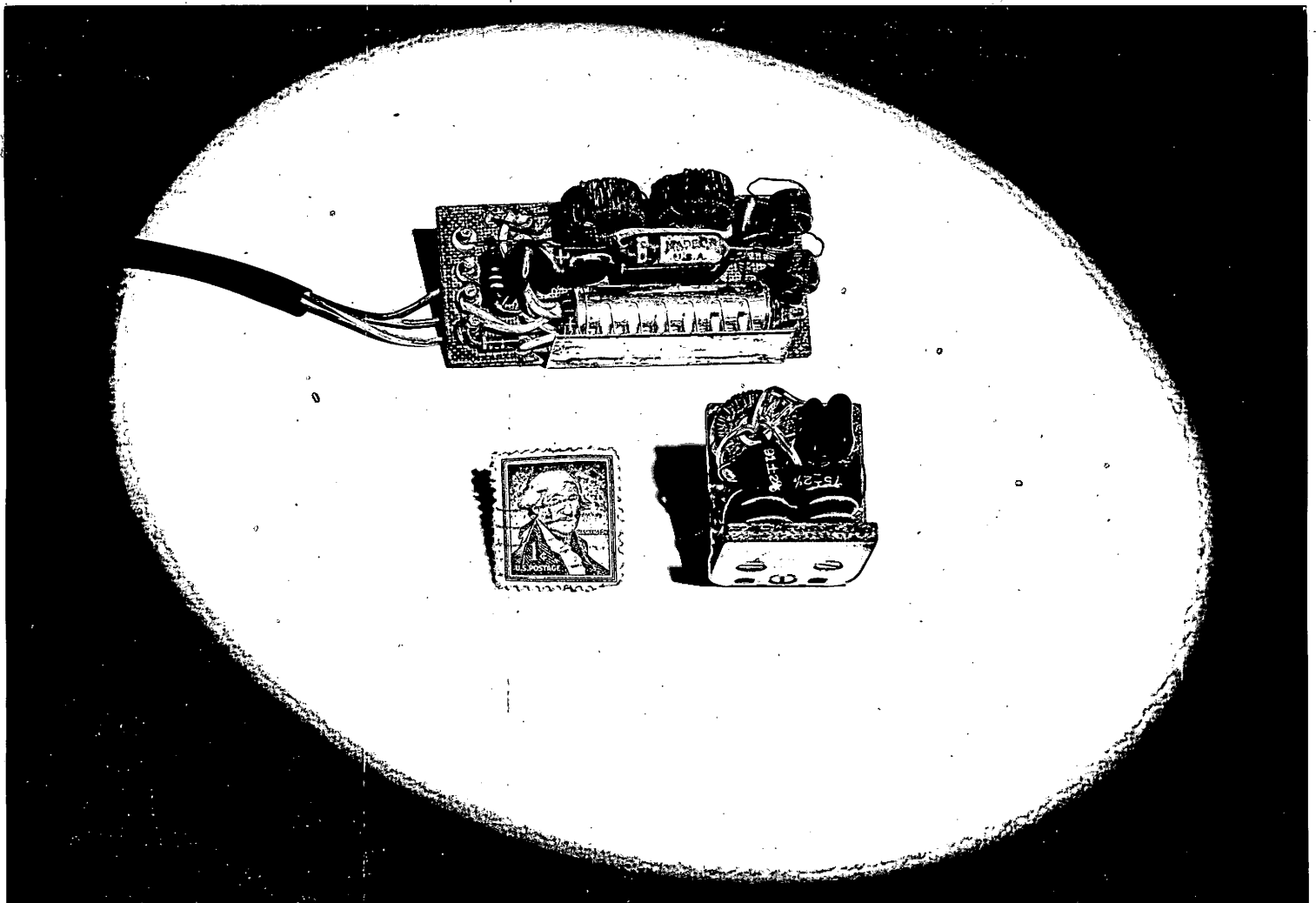
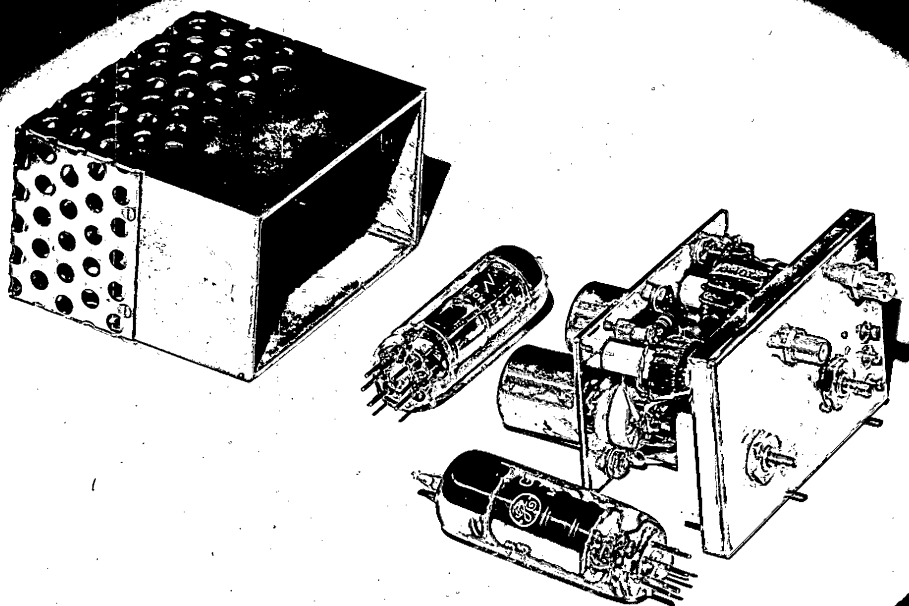


Figure 11 a

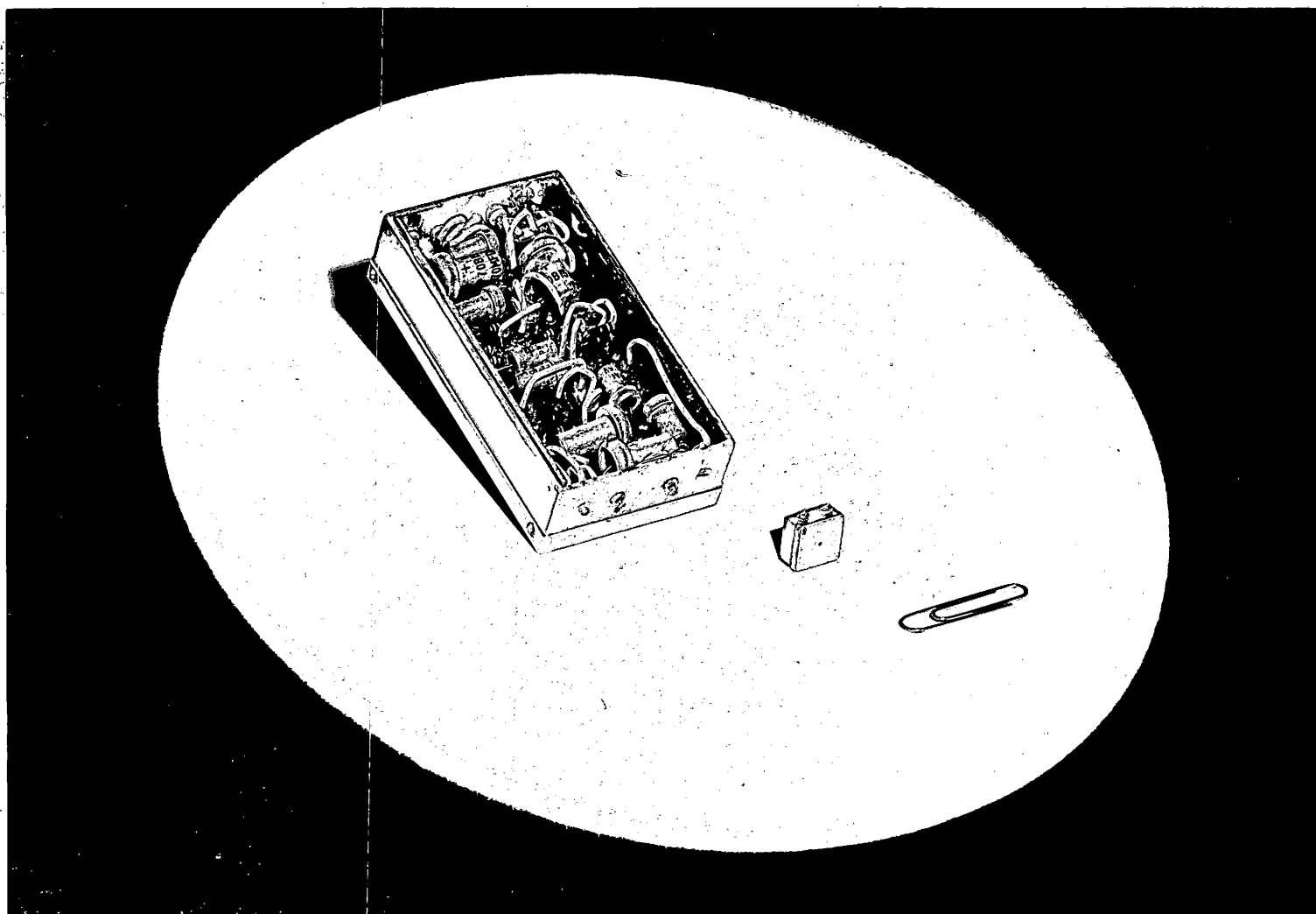


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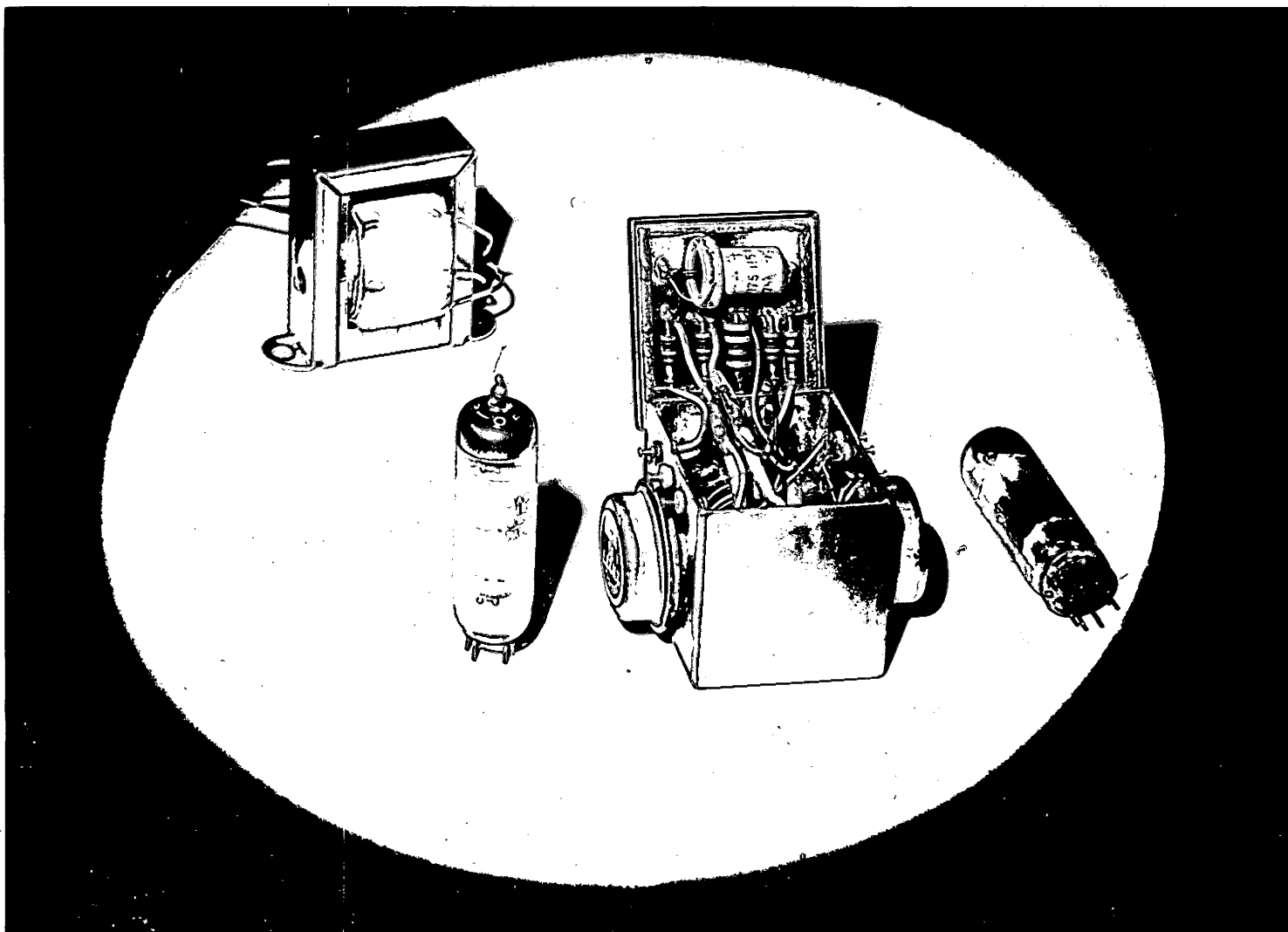
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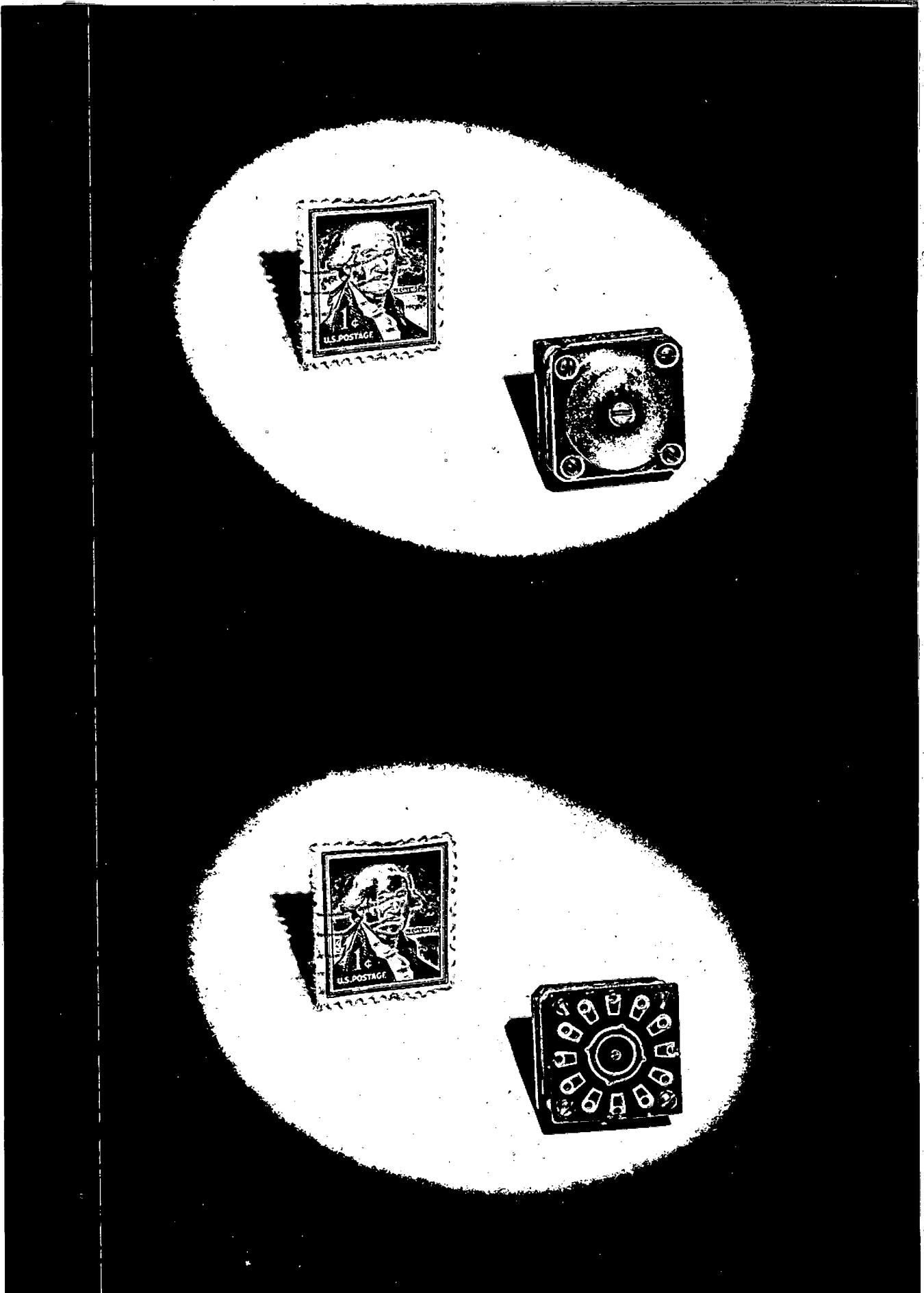


FIG. 17 MINIATURE SWITCH

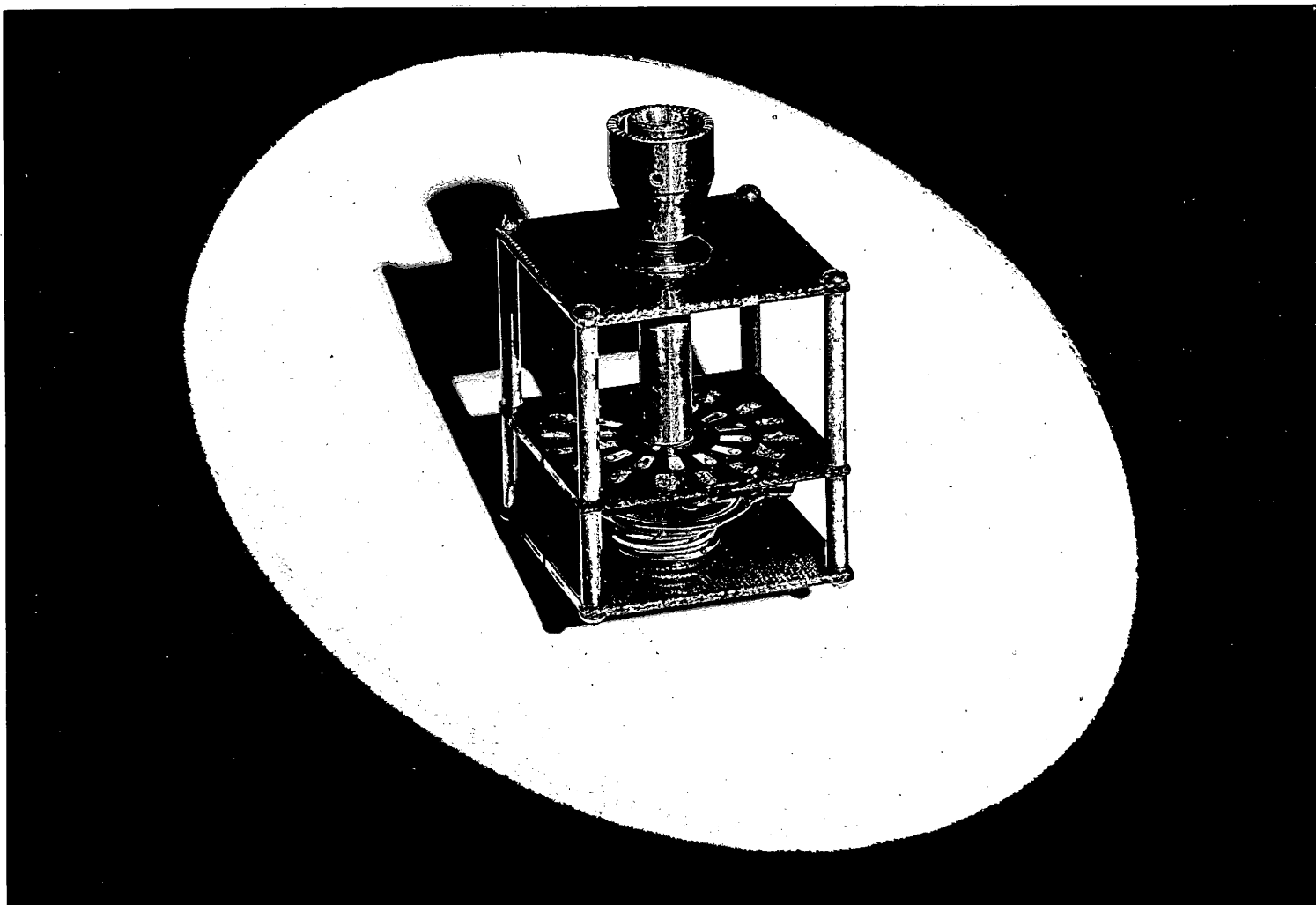


FIG. 10. DUAL CONTROL CONCENTRIC SHAFT SWITCH